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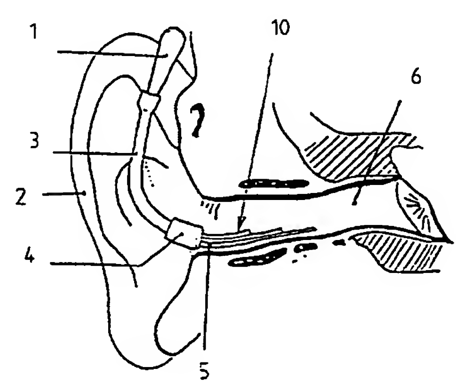
(54) Hearing aid

(57) A hearing aid with a microphone, an amplifier arrangement connected to the microphone and a sound generator energized by the amplifier and having an output connected to a sound guide structure (10, 10', 10") which is directed toward an ear, or respectively, an eardrum of a user, wherein between the auditory canal (6) and the sound guide structure (10' ,10', 10"), a gap remains permitting passage of ambient sounds. In order to prevent fringe haul-generating feedback coupling in spite of the small and compact dimensions of the hearing aid, the sound guide structure (10, 10' 10") includes a plurality of air containing channels of different lengths having staggered sound discharge openings.

Fig. 1



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Description

The invention relates to a hearing aid in accordance with the preamble of claim 1.

Such equipment which has become known as hearing aid with open adaptation, consists generally of a device worn behind the ear with a sound tube extending into the ear lobe or the auditory canal without tightly closing the auditory canal. Such adaptations are possible of course only with minimal amplification and a totally linear frequency characteristic since otherwise, feed back coupling with fringe haul would be unavoidable.

Another open adaptation which is only rarely used is the so-called "Cros-hearing aid" which is always separated into two parts of which the microphone is worn at one side of the head and the ear piece or sound emitter at the other. This type of hearing aid is generally used only if the sensitivity of the two ears of a person with hearing defects is very different. Such devices are not subject to feed back coupling because there is a relatively large distance between the microphone and the ear piece.

With the usual hearing aids such as those arranged in the outer ear or in the auditory canal, the auditory canal is practically fully closed by the ear piece whose sound discharge opening is in the interior of the auditory canal. The microphone of such a hearing aid is in communication with a sound entrance opening at an exposed outer side of a housing of such a hearing aid. The tight fit of such a hearing aid in the ear of a user prevents feed back coupling.

If a person is exposed to loud noises for an extended period his or her ear may be damaged for some time or permanently. This may result in communication problems in special situations. Since the hearing loss so generated is usually not severe "normal" hearing aids with which the auditory canal of an ear is totally closed cannot be used or they are a nuisance. There is actually no suitable technical aid available for such persons.

People with almost normal hearing usually have a hearing loss in the high frequency range (4-6 kHz) while their hearing is quite normal in the range up to 2 kHz. With a good signal-to-noise ratio such persons have no problems to understand. Problems arise only when it becomes noisy. Typical examples where problems with understanding would occur are for example visits in restaurants and coffee houses, on busy streets, when watching television, etc....

A disadvantage of the normal hearing aid is further that, in order to prevent feed back coupling and acute fringe haul, the ear is closed (sealed). In addition, the transmission range toward higher frequencies is not good and there are problems in determining the direction from which a sound is coming. Also, hearing aids do not have a good image. For this reason, hearing aids are often not used even if a person would really need to wear one.

The state-of-the-art for the correction of this kind of hearing losses includes the so-called high sound frequency hearing aids. These are hearing aids which amplify only the higher sound frequencies, whereas the lower frequencies are not amplified. But even these hearing aids can hardly be used by the group of people referred to above. Generally, the amplification of sounds of 1 kHz and higher is quite high so that the hearing aid has feed back coupling tendencies. To avoid this, a tight ear shell is generally used which, however, is somewhat awkward to wear. Furthermore, the reproduction quality and the sound localization capabilities are limited. Also these hearing aids are almost always custom made and, consequently, expensive. Finally, the auditory canal is tightly closed which prevents normal hearing in the low frequency sound range.

It is the object of the invention to overcome these disadvantages and to provide a hearing aid of the type as referred to initially, which is particularly suitable to compensate for a hearing loss in the high frequency sound range.

In accordance with the invention, this is achieved with a hearing aid of the type as described earlier by the features given in the characterizing part of claim 1.

With the multitude of channels which, according to the invention, have sound discharge openings which are displaced relative to each other a directional sound effect is achieved in a simple manner such that the sound exits the essentially straight tubes or hoses essentially in an axial direction. As a result, there is no feed back coupling inspite of the fact that the auditory canal is not sealed off and the microphone is arranged close to the sound generator such that in the low frequency range normal hearing is possible.

Since the auditory canal is not closed by the hearing aid it is not necessary to fit the hearing aid into the ear so that it does not need to be custom-made whereby it can be manufactured at relatively low cost. Furthermore, the hearing aid can be designed as desired such that the device could be incorporated for example into earrings or another jewelry piece. The hearing aid with microphone, amplifier and if applicable with filter for achieving a certain transmission function and the sound generator as they are commonly used with today's ear internal or auditory canal hearing aids, can be highly miniaturized.

Preferably, the amplifier is a high frequency amplifier which amplifies only in the high sound frequency range, for example, from about 4 kHz by 10 to 20 dB. This can be determined for example by means of a filter associated with the amplifier for selecting the respective transmission frequencies. In this way, the sounds can be selectively amplified only in the high frequency range in a simple manner whereas, in the low frequency sound range, direct hearing by way of the open auditory canal is insured.

With the features of claim 2, a relatively simple

sound guide arrangement is achieved which has a substantial directional effect with regard to the sound emission. With this sound guide arrangement, the signals from the various tubes arrive at the same time at an axial point in front of the sound discharge openings and are added up provided that the sound speed in the tubes equals the sound speed in the air. However, at a point behind the hearing aid, that is adjacent the microphone, the signals from the various tubes arrive with a phase shift and can therefore not be added up properly or, under advantageous conditions, cancel each other. As a result, there is no feedback coupling even if the distance between the microphone and the sound generator is relatively small since the sound level curves of the microphone and those of the sound generator which have suitably directional effects, are for example in the shape of a kidney and do practically not overlap.

The features of claim 3 have the advantage that such a sound guide arrangement can be manufactured in a relatively simple manner.

In accordance with the features of claim 4, an multi-chamber hose as it is known per se in medical technology is provided as a sound guide structure.

The features of claim 5 provide for a large number of sound discharge openings. The fact that the sound pressure becomes smaller with the distance from the sound source that is the sound generator is accommodated by the wedge-like shape of the slot.

Such a sound guide structure can be arranged for example in a simple manner at the frame of hearing glasses wherein the free end of the sound guide structure is directed toward the ear.

The invention will be explained below on the basis of the drawings wherein:

Figs. 1 and 2 show schematically different embodiments of the hearing aid according to the invention,
Fig. 3 shows schematically the sound level curves of a microphone-sound generator arrangement as it applies to a hearing aid according to the invention,
Figs. 4 and 5 show various embodiments of sound guide structures,
Fig. 6 shows a multi-chamber hose in cross-section,
Fig. 7 shows another embodiment of a sound guide structure for a hearing aid according to the invention, and
Fig. 8 shows a measuring arrangement by which the diagrams of Figs. 9 to 11 were recorded.

Fig. 1 shows schematically a hearing aid according to the invention inserted into an ear. A hearing aid containing a microphone, an amplifier and a sound generator is supported on an earhook 1 behind the ear 2 of a user. The earhook 1 is hollow and a hose 3 is connected to the earhook 1 and leads to a connecting socket 4. Connected to this connecting socket 4 are several tubes or hoses 5 of different lengths such that their front end sound discharge openings are staggered in axial direction of the tubes or hoses 5. These tubes or hoses 5 form a sound guide structure 10 which provides a directional effect for the sound discharge in the direction of the longitudinal axis of the tubes or hoses 5.

The tubes or hoses 5 extend into the auditory canal 6 of the user.

In the embodiment according to Fig. 2, the hearing aid is disposed in the frame 7 of hearing glasses 8. A sound guide structure 10' is attached to the sound generator 9. The sound guide structure 10' will be described in greater detail. The free front end of the sound guide structure 10 is directed toward the ear of the user which is not shown. As a result, the auditory canal remains open permitting normal hearing, particularly in the low sound frequency range, like with the arrangement according to Fig. 1. Also, at least in the low sound frequency range a directional orientation capability remains although in a limited way provided both ears are capable of hearing.

An essential problem with hearing aids by which the auditory canal is not closed resides in the possibility of feedback coupling between the sound generator and the microphone whereby the well-known fringe haul occurs. For this reason, the microphone and the sound generator are arranged in such hearing aids at a distance from one another wherein the known hearing aids utilize sound generators without directional effects.

The polar coordinate diagram of Fig. 3 shows in full lines the condition with a microphone-sound generator arrangement with a normal microphone 11 with directional characteristics and a sound generator 13 also with directional characteristics as it is used in the hearing aid according to the invention.

As can be seen from Fig. 3, the kidney shaped sound level curves 12 of the microphone 11 and the also kidney-shaped sound level curve 14 of the sound generator 13 do not overlap so that there is little tendency for a feedback coupling of the arrangement. A microphone which is suitable for an ear phone and which has appropriate directional characteristics could be for example, a pressure gradient microphone.

As shown by the dashed lines the sound level curve 12 of the microphone 11 would overlap the sound level curve 15 of a sound generator without directional characteristics so that the chances of feed back coupling would be very high with such an arrangement.

Also, loudspeakers with directional characteristics are well known for the purpose of acoustic irradiation. For this purpose acoustic arrays are used where several single loudspeakers are arranged side-by side in a line so as to define a front for the sound wave generated thereby and, accordingly provide a directional effect. Furthermore, also some passive methods are known whereby with acoustic lenses the front of the wave and, consequently, the directional characteristics can also be controlled. In principle, all methods can be reduced to the following two processes. Firstly, several cooperating

converters (at least two) are used. The second possibility is to use acoustic lenses or other passive means. For the application described herein a combination of the different methods may be used for price and space reasons. The main player herein is the loudspeaker (sound generator) where solutions for hearing aids with their given smallness are not common or rather not known up to now.

With hearing aids according to the invention, the frequency range in which the directional effects of the sound generator is essential is relatively high and, consequently, the wave length is small. As a result, the required directional effect can be obtained also by passive solutions.

A possible arrangement for a directional sound generation for a hearing aid in accordance with the invention is shown in principle in Fig. 4. It includes a sound generator 9 with a sound discharge structure comprising several tubes 5. Each tube 5 has a different length. Seen in an axial direction (0°) and assuming that the sound speed within the tubes 5 is the same as in air, all the signals from the different tubes arrive at the point A at the same time and are added up. However, the signals arrive at point B with a phase shift with regard to each other. They are therefore improperly added up and, under favorable conditions, they even cancel each other. With a given delay, the phase shift is frequency dependent which also results in a frequency dependent directional characteristic. It is to be noted that, actually, the sound speed in the tubes is smaller than in air if the tube diameter is substantially smaller than the wave length.

Since the frequency range of a hearing aid, in which the sound should be amplified and in which a corresponding directional characteristic of the sound discharge of the sound generator 9 is required, is relatively narrow and can usually be kept smaller than 4 kHz, hardly any problems are experienced since a relatively small number of tubes or hoses 5 are sufficient. As a result, also the diameters of the tubes or hoses 5 remain in a size range in which they can be relatively easily manufactured.

As explained already on the basis of Fig. 1, it is not absolutely necessary to connect the tubes or hoses 5 of different lengths directly to the sound generator 9. It is possible to connect to the sound generator 9 a sound hose 3 in the usual way and to connect the tubes or hoses 5 to the end of the sound hose 3 by means of a connecting socket 4. The socket 4 may be formed by a slip or shrinkable hose piece which interconnects the tubes or hoses 5 with the sound hose 3 which generally consists of a plastic hose having an inner diameter of 2 mm.

With such a sound guide structure with seven tubes or hoses 5 and a difference in length between the shortest and the longest tube or hose 5 of about 20 mm, a forward/backward ratio of about 15 dB could be reached at a frequency of about 3150 Hz.

Fig. 5 shows another embodiment of a sound guide structure 10" for a hearing aid according to the invention. In this embodiment, a sound hose 3 is connected by way of a connecting socket 4, which may be a slip or shrinkable hose section, to a multi-chamber hose 31 having a cross-section as shown in Fig. 6. Herein the chambers 32, 33 34, 35 have different length by a stepped cut.

As shown in Fig. 5, the chamber 32 has the shortest length whereas chamber 33 has a greater length, which is again exceeded by the length of chamber 34. The central chamber 35 has the greatest length.

Basically, the absolute lengths of the chambers 32, 33, 34, 35 of the embodiments shown in Figs. 5 and 6 as well as the lengths of the tubes or hoses 5 of Fig. 4 are not critical. What is important is only the length difference between the shortest and the longest tube or hose 5 or respectively, the lengths difference between the shortest and the longest chambers 32 and 35.

Fig. 7 shows another embodiment of a sound guide structure 10' for the hearing aid according to the invention. It includes a sound generator 9 connected to a tube 16 whose interior is filled with an open pore foamed material 17 which includes a wedge-shaped slot 18. The slot 18 is open at the free front end 19 of the tube 16 and there it has its greatest width. The slot 18 ends in front of the sound generator 9.

This sound guide structure 10' includes an almost infinite number of discharge openings wherein the wedge-like form of the slot 18 takes into account that the sound pressure in the foamed material 17 as well as in all other media decreases with the distance from the sound generator.

Fig. 8 shows a measuring arrangement for the polar diagrams of Figs. 9 - 11 by which the directional characteristics of the arrangement as shown in Fig. 4 were recorded. The arrangement is designated by the numeral 20. Sound is supplied to the tubes or hoses 5 by a sound generator 9 which is energized by way of an amplifier 21. The amplifier 21 receives its input signal from a frequency generator FG by way of an inductive system 27 in order to permit a rotation of the arrangement for recording the polar diagram. The sound is recorded by a measuring microphone 23. Note the different dB scales in Figs. 9 and 10. Fig. 11 shows the whole diagram in another representation (surface diagram).

Claims

1. A hearing aid with a microphone, an amplifier arrangement connected to the microphone so as to receive signals therefrom and connected to a sound generator for supplying amplified signal thereto, a sound guide structure (10, 10', 10") connected to the sound generator and being directed toward an ear or, respectively, an ear drum of a user, wherein between the auditory canal (6) and

the sound guide structure (10, 10', 10"), a gap remains which permits the passage of ambient sound, **characterized in that** the sound guide structure (10, 10', 10") is formed by a multitude of air containing channels which have different lengths and sound discharge openings which are displaced from one another.

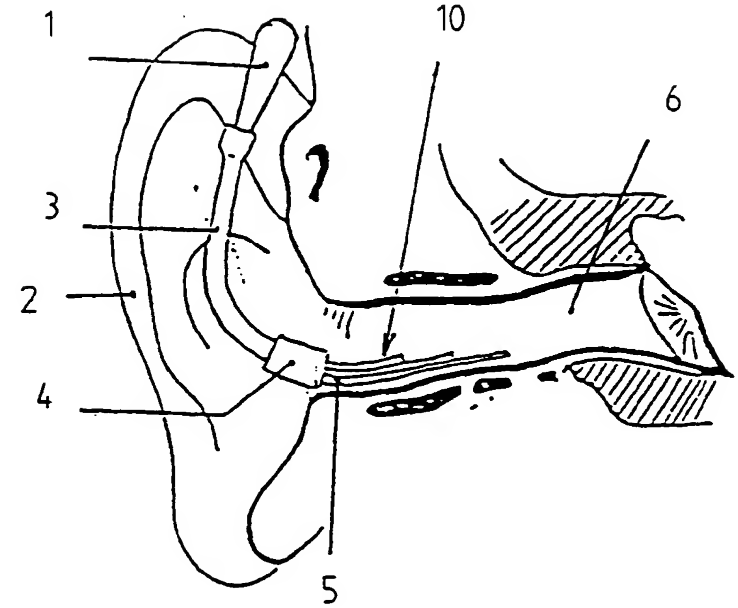
2. A hearing aid according to claim 1, **characterized in that** the sound guide structure is formed by a plurality of tubes or hoses (5) which have different lengths and front end sound discharge openings which are arranged staggered in the axial direction of the tubes or hoses (5).

3. A hearing aid according to claim 2, **characterized in that** the sound generator (9) is connected to a connecting socket (4) by way of a connecting hose (3) and the plurality of tubes or hoses (5) have an inner diameter which is substantially smaller than that of the connecting hose and are all mounted in the connecting socket.

4. A hearing aid according to claim 1, **characterized in that** the sound guide structure (10") comprises a multi-chamber hose (31) which includes individual chambers (32, 33, 34, 35) of different lengths.

5. A hearing aid according to claim 1, **characterized in that** the sound guide structure (10') comprises a tube (16) filled with an open-pore foamed material (17) which is connected to the sound generator (9) and has a free end directed toward the ear of a user and which includes a wedge-like slot (18) having its widest end at the front end (19) of the tube (16) directed toward the user and which ends adjacent the sound generator (9).

Fig. 1



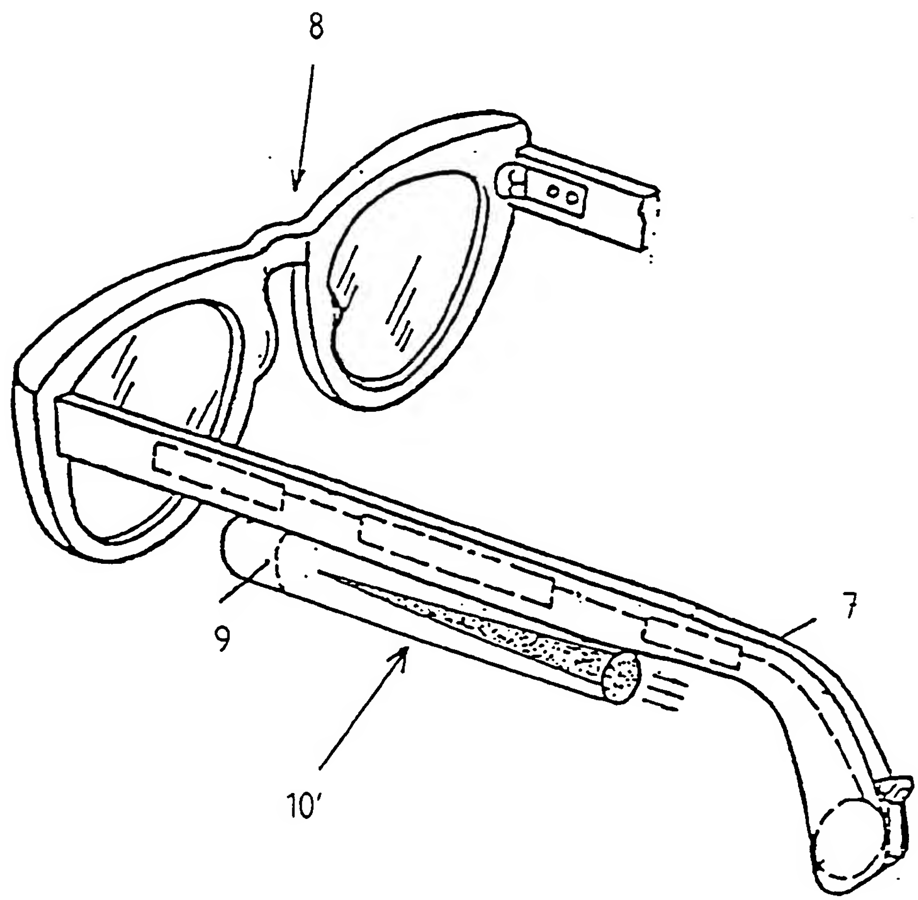


Fig. 2

Fig. 3

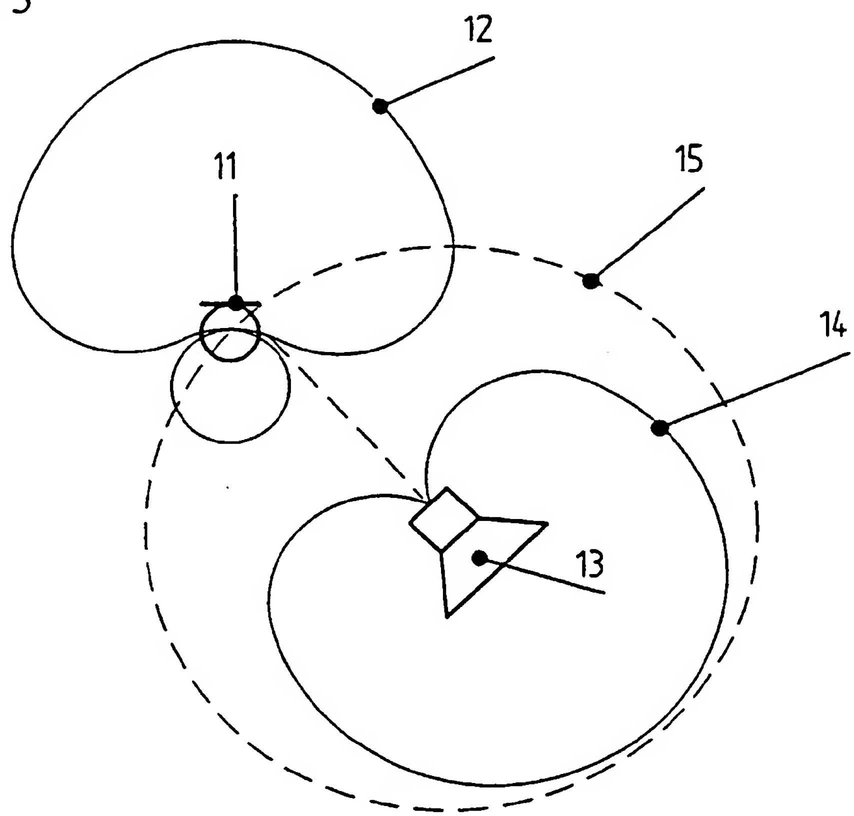


Fig. 4

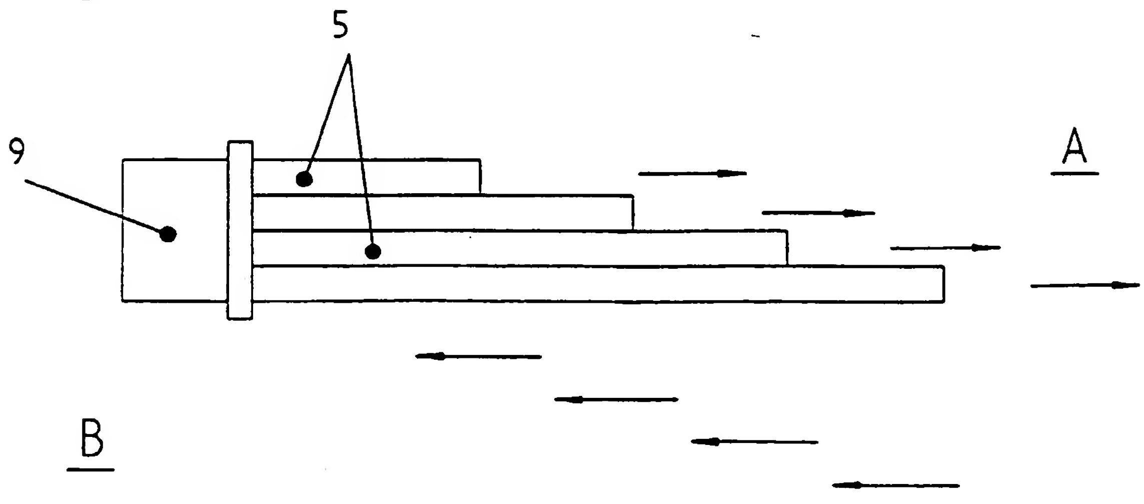


Fig. 5

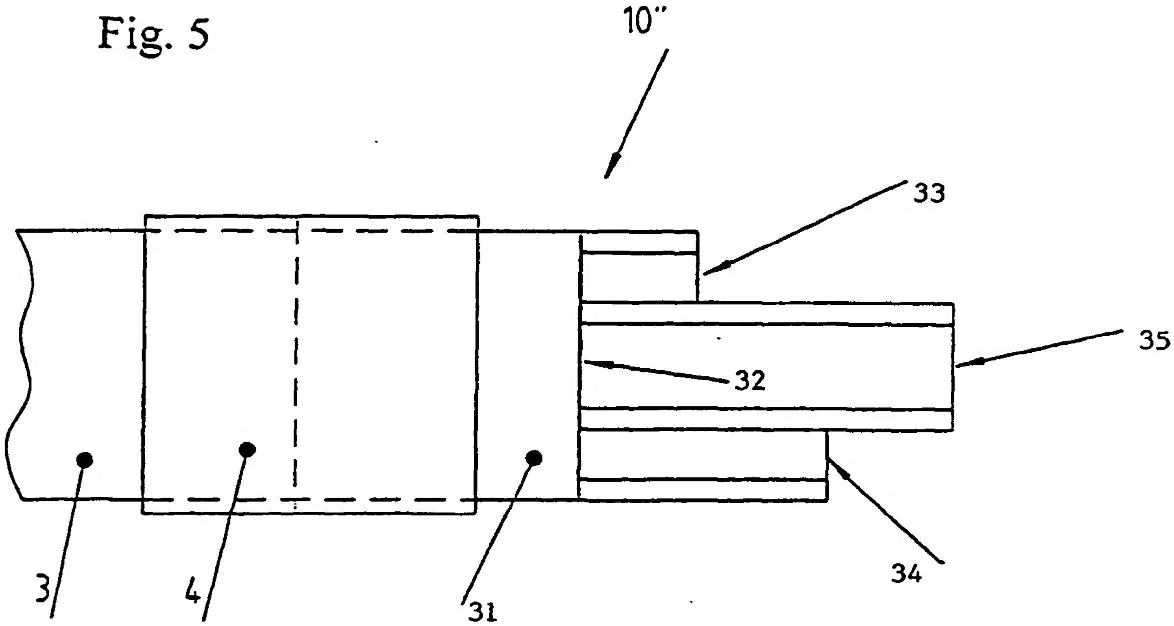


Fig. 6

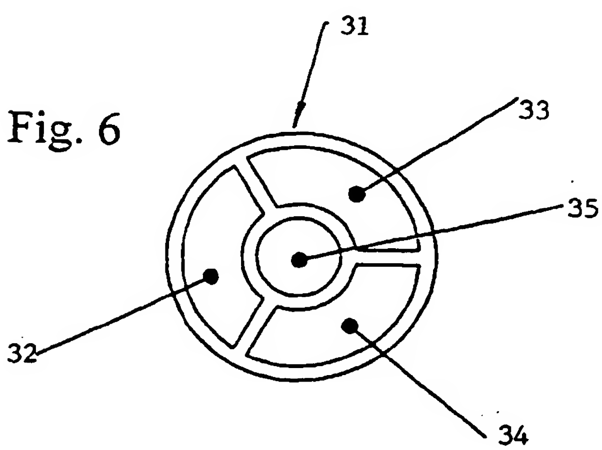


Fig. 7

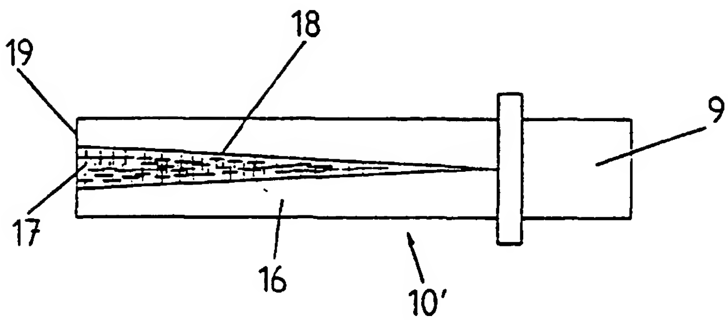
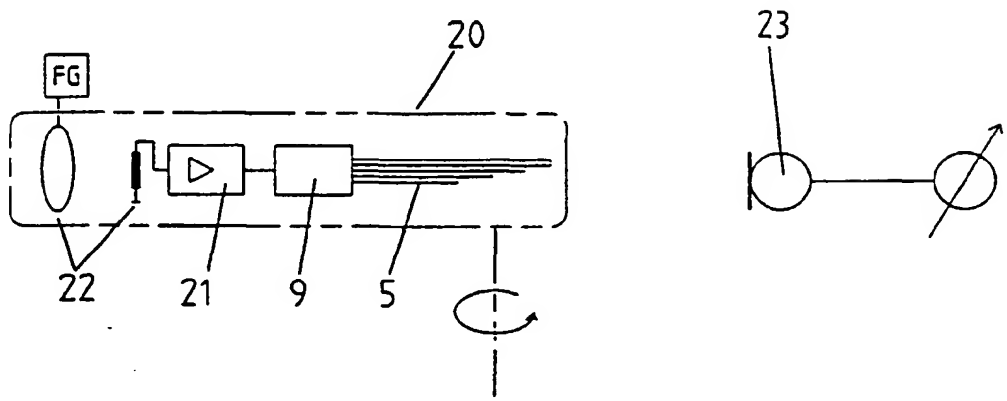


Fig. 8



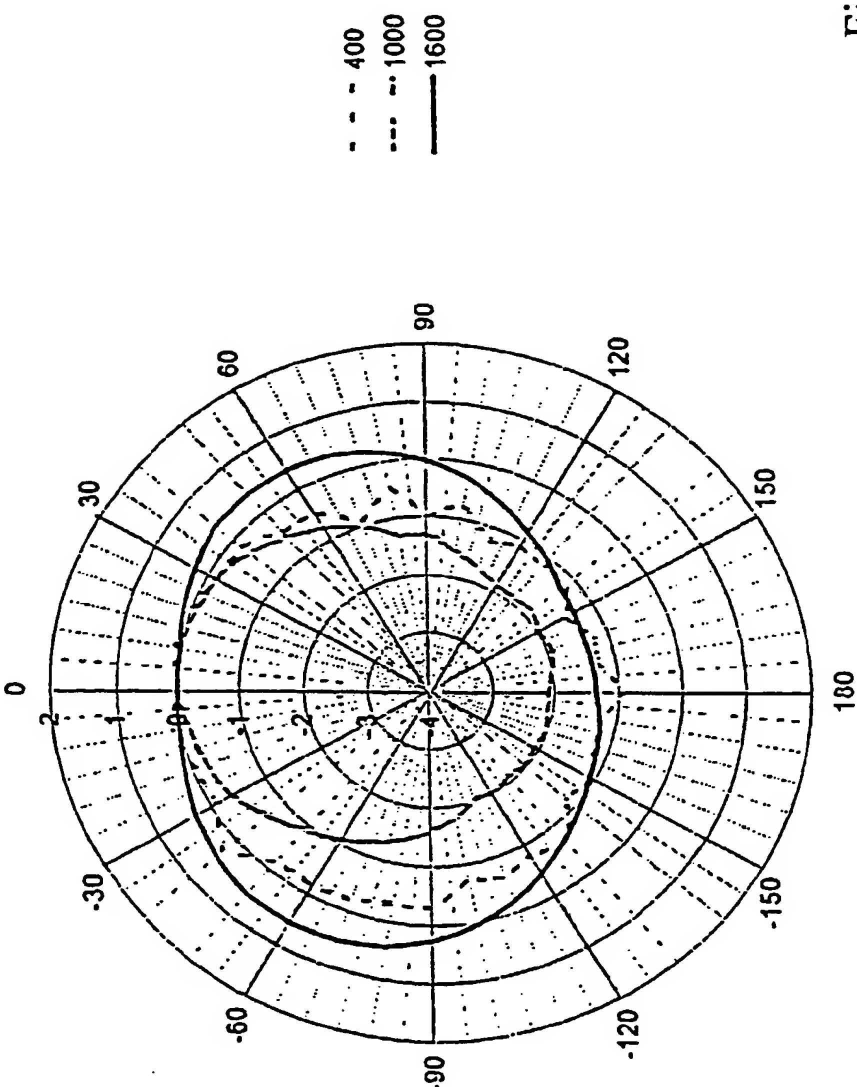


Fig. 9

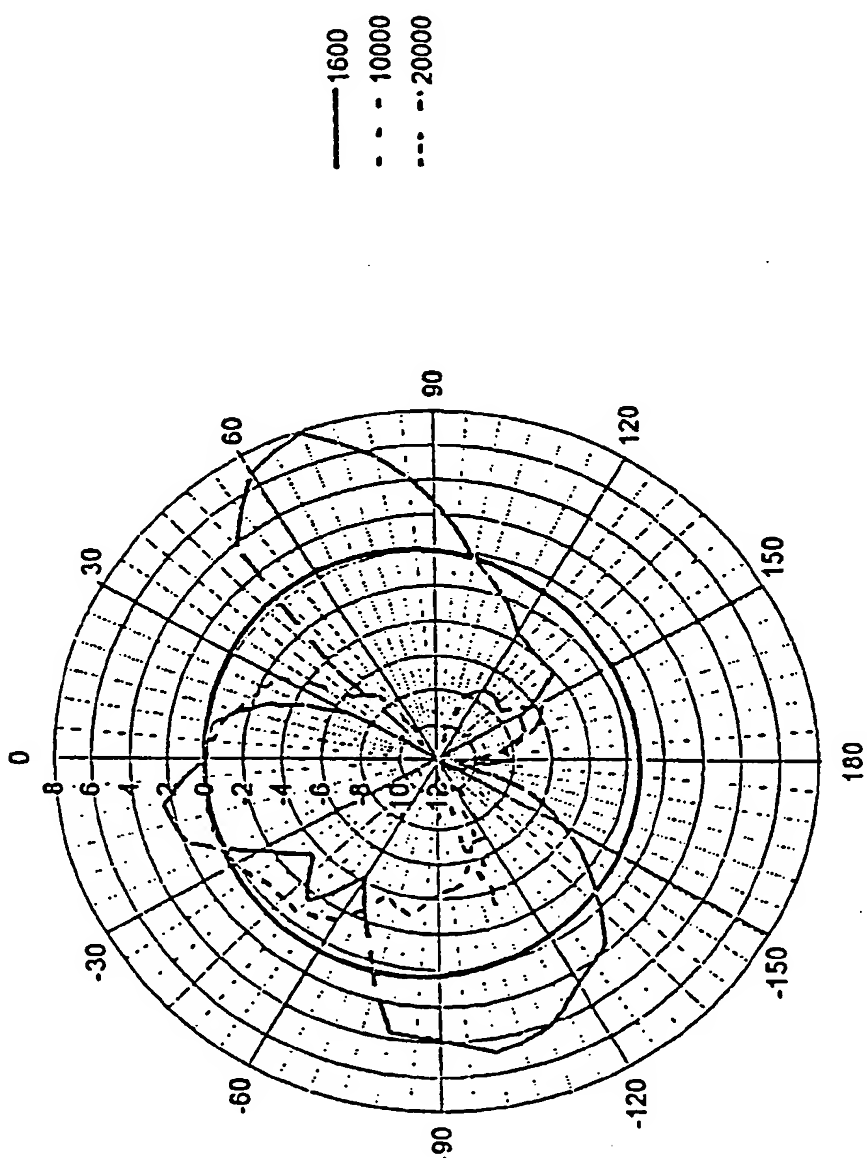

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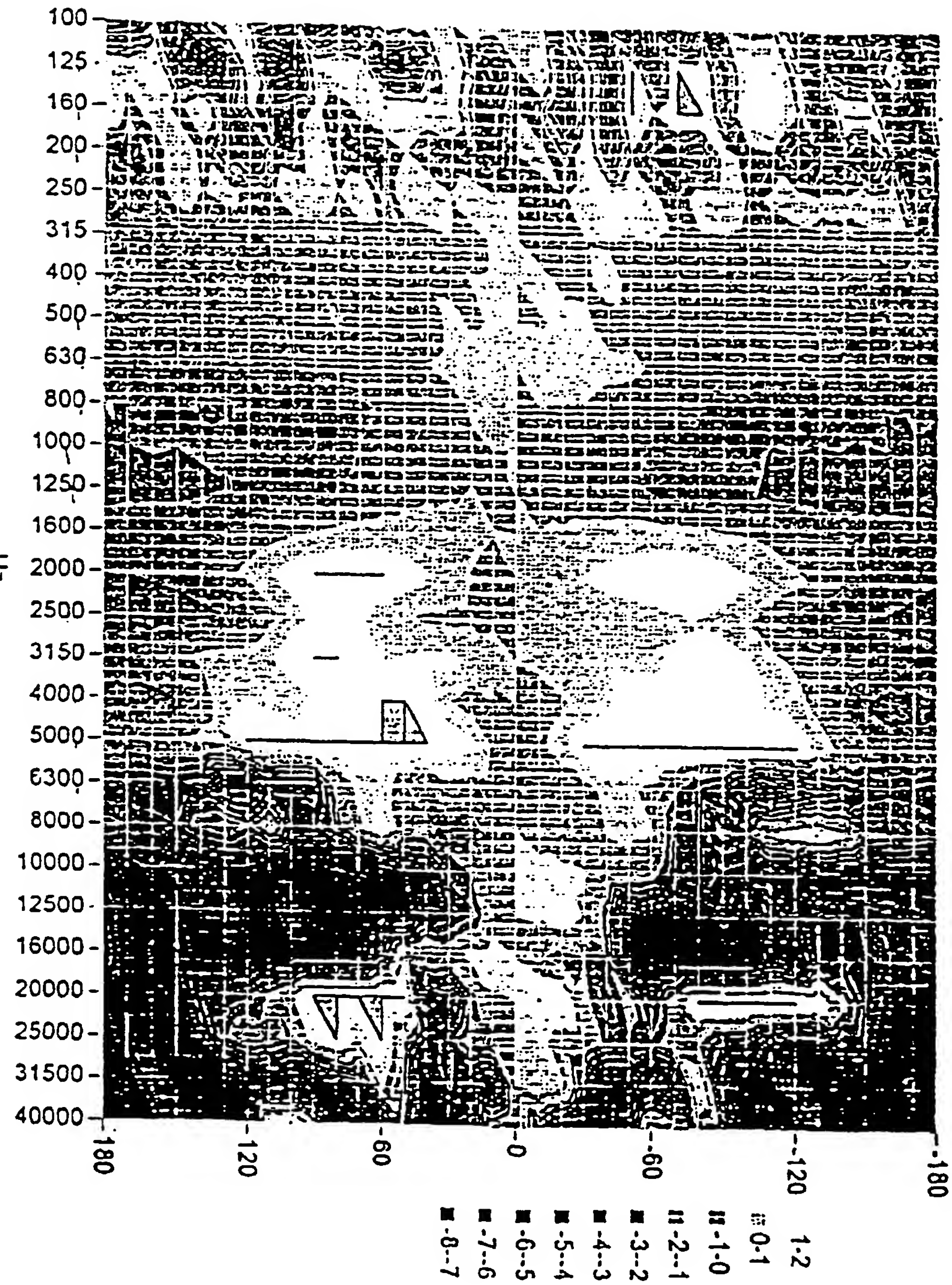
Fig. 10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-2--1
-3--2
-4--3
-5--4
-6--5
-7--6
-8--7

Fig. 11